High-Efficiency Multibandgap Solar Cell Being Developed

Current high-efficiency solar cells are based on lattice-matched materials, specifically indium gallium phosphide (InGaP) on gallium arsenide (GaAs) on germanium (Ge). These materials were chosen more for their lattice constant (spacing between atoms) than their ability to efficiently convert the solar spectrum. Theoretical analysis indicates that the optimum efficiency for a multijunction solar cell would utilize very different bandgap cells. Unfortunately, no group of materials satisfies both the lattice-match and optimum bandgap requirements. The projected efficiency of the current state-of-the-art dual-junction InGaP/GaAs solar cell is ~29 percent (at air mass zero, AM0). If the optimum bandgaps could be utilized, the projected efficiency would increase to ~33 percent.

The use of lattice-mismatched materials has been avoided because the mismatch generates performance-robbing defects. Several novel buffer-layer concepts are being developed to mitigate these problems. Under a Small Business Innovation Research contract with the NASA Glenn Research Center at Lewis Field**,** Essential Research is developing an optimized dual-junction, lattice-mismatched solar cell based on indium aluminum gallium phosphide (InGaAlP) on indium gallium arsenide (InGaAs). These devices are lattice matched to each other, but lattice mismatched to either GaAs or Ge substrates. A novel InGaAs buffer layer has been demonstrated that effectively reduces the deleterious effects of lattice mismatching. Current test devices have projected efficiencies of 26 percent at AM0. Three- and four-junction bandgap-optimized, lattice-mismatched solar cells are also being developed.

NASA Glenn and the Ohio State University are exploring the use of silicon substrates for III–V photovoltaic devices through a novel silicon germanium (SiGe) buffer layer developed by Professor Fitzgerald at Massachusetts Institute of Technology (MIT) and Amberwave. Researchers have long wanted to use silicon for such devices because of silicon’s low cost, low mass, and high strength. Unfortunately, the large lattice mismatch (4 percent) and the difference in thermal expansion coefficient between Si and GaAs have so far prevented the demonstration of high-efficiency III–V devices on Si. MIT and Ohio State have recently demonstrated world-record lifetimes (10 nsec) for AlGaAs/GaAs double heterostructures grown on the SiGe/Si substrates. In addition, they have measured dislocation densities in GaAs grown on these substrates of $<10^{-6}$ cm^{-2}. These results provide encouragement that transitioning these high-efficiency III–V cells to low-cost, lightweight Si substrates may soon be possible.

Glenn contacts: David M. Wilt, (216) 433–6293, David.M.Wilt@grc.nasa.gov; and Dr. Dennis J. Flood, (216) 433–2303, Dennis.J.Flood@grc.nasa.gov

Author: David M. Wilt

Headquarters program office: OAST

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